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(54) Title: COATED MILLING INSERT AND METHOD OF MAKING IT

(57) Abstract

The present invention discloses a coated milling insert particularly useful for milling in low and medium alloyed steels with or without raw surface zones during wet or dry conditions. The insert is characterized by a WC-Co cemented carbide with a low content of cubic carbides and a highly W-alloyed binder phase and a coating including an inner layer of $TiC_xN_yO_z$ with columnar grains, an inner layer of κ-Al_2O_3 and, preferably, a top layer of TiN. The layers are deposited by using CVD-methods.

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COATED MILLING INSERT AND METHOD OF MAKING IT

The present invention relates to a coated cutting tool (cemented carbide insert) particularly useful for wet and dry milling of low and medium alloyed steels, with raw surfaces such as cast skin, forged skin, hot or cold rolled skin or pre-machined surfaces.

When milling low and medium alloyed steels with cemented carbide tools the cutting edge is worn according to different wear mechanisms, such as chemical wear, abrasive wear, adhesive wear and by edge chipping caused by cracks formed along the cutting edge, the so called comb cracks.

The comb crack formation is particularly severe when wet milling is employed (using coolant). Coolant and work piece material may penetrate and widen the comb cracks and the edge will start to chip. A chipped edge will generate a bad surface finish of the machined component.

Different cutting conditions require different properties of the cutting insert. For example, when cutting in steels with raw surface zones a coated cemented carbide insert must consist of a tough carbide and have very good coating adhesion. When milling in low alloyed steels the adhesive wear is generally the dominating wear type. Here preferably thin (1-3 µm) CVD- or PVD-coatings have to be used.

Measures can be taken to improve the cutting performance with respect to a specific wear type. However, very often such action will have a negative effect on other wear properties.

The influence of some possible measures is given below:

1.) Comb crack formation can be reduced by lowering the binder phase content. However, such action will

lower the toughness properties of the cutting inserts which is not desirable.

2.) Improved abrasive wear can be obtained by increasing the coating thickness. However, thick coatings increase the risk for flaking and will lower the resistance to adhesive wear.

3.) Milling at high cutting speeds and at high cutting edge temperatures requires a cemented carbide with a rather high amount of cubic carbides (solid solution of WC-TiC-TaC-NbC). Such carbides will more easily develop comb cracks.

So far it has been very difficult to improve all tool properties simultaneously. Commercial cemented carbide grades have therefore been optimized with respect to one or few of these wear types and hence to specific application areas.

Swedish patent application 9501286-0 discloses a coated cutting insert particularly useful for dry milling of grey cast iron. The insert is characterized by a straight WC-Co cemented carbide grade and a coating including a layer of $TiC_xN_yO_z$ with columnar grains and a top layer of fine grained textured α-Al_2O_3.

Swedish patent application 9502640-7 discloses a coated turning insert particularly useful for intermittent turning in low alloyed steel. The insert is characterized by a WC-Co cemented carbide body having a highly W-alloyed Co-binder phase and a coating including a layer of $TiC_xN_yO_z$ with columnar grains and a top layer of a fine grained, textured α-Al_2O_3.

Swedish patent application 9503056-5 discloses a coated turning cutting tool particularly useful for cutting in hot and cold forged low alloyed steel. The insert is characterized by a WC-Co cemented carbide body having a highly W-alloyed Co-binder phase and a coating

including a layer of $TiC_xN_yO_z$ with columnar grains and a top layer of a fine-grained, α-Al_2O_3.

It has now surprisingly been found that by combining many different features a cutting tool for milling with excellent cutting performance in low and medium alloyed steel with or without raw surface zones both in wet and dry milling can be obtained. The cutting tool according to the invention shows improved properties with respect to many of the wear types earlier mentioned.

The milling cutting insert according to the invention consists of: a cemented carbide body with a highly W-alloyed binder phase and with a well balanced chemical composition and grain size of the WC, a columnar $TiC_xN_yO_z$-layer, a κ-Al_2O_3-layer, a TiN-layer and optionally followed by smoothening the cutting edges by brushing the edges with e.g. a SiC based brush.

Fig 1 is a micrograph in 10000 X magnification of a coated insert according to the present invention in which

A - cemented carbide body

B - $TiC_xN_yO_z$-layer with equiaxed grains

C - $TiC_xN_yO_z$-layer with columnar grains

D - κ-Al_2O_3-layer with columnar like grains

E - TiN-layer preferred, could be an option

According to the present invention a milling tool insert is provided with a cemented carbide body with a composition of 8.6-9.5 wt% Co, preferably 8.7-9.5 wt% Co, most preferably 8.8-9.4 wt% Co, 0.2-1.8 wt% cubic carbides, preferably 0.4-1.8 wt% cubic carbides, most preferably 0.5-1.7 wt% cubic carbides of the metals Ta, Nb and Ti and balance WC. The cemented carbide may also contain other carbides from elements from group IVb, Vb or VIb of the periodic table. The content of Ti is preferably on a level corresponding to a technical impu-

rity. The average grain size of the WC is in the range of about 1.5-2 µm, preferably about 1.7 µm.

The cobalt binder phase is highly alloyed with W. The content of W in the binder phase can be expressed as the CW-ratio= M_S / (wt% Co · 0.0161), where M_S is the measured saturation magnetization of the cemented carbide body in kA/m and wt% Co is the weight percentage of Co in the cemented carbide. The CW-value is a function of the W content in the Co binder phase. A low CW-value corresponds to a high W-content in the binder phase.

It has now been found according to the present invention that improved cutting performance is achieved if the cemented carbide body has a CW-ratio of 0.78-0.93, preferably 0.80-0.91, and most preferably 0.82-0.90. The cemented carbide may contain small amounts, <1 volume %, of η-phase (M_6C), without any detrimental effect. From the CW-value it follows that no free graphite is allowed in the cemented carbide body according to the present invention.

The cemented carbide body may contain a thin (about 5-25 µm) surface zone depleted in cubic carbides and often enriched in binder phase according to prior art such as disclosed in US 4,610,931. In this case the cemented carbide may contain carbonitride or even nitride.

The coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, preferably z<0.5, with equiaxed grains with size <0.5 µm and a total thickness <1.5 µm and preferably >0.1 µm.

- a layer of $TiC_xN_yO_z$ with x+y+z=1, preferably with z=0 and x>0.3 and y>0.3, with a thickness of 1-6 µm, preferably 2-5 µm, with columnar grains and with an average diameter of about <5 µm, preferably 0.1-2 µm

- a layer of a smooth, fine-grained (grain size about 0.5-2 µm) Al_2O_3 consisting essentially of the κ-

phase. However, the layer may contain small amounts, 1-3 vol-%, of the θ- or the α-phases as determined by XRD-measurement. The Al_2O_3-layer has a thickness of 0.5-5 µm, preferably 0.5-2 µm, and most preferably 0.5-1.5 µm. Preferably, this Al_2O_3-layer is followed by a further layer (<1 µm, preferably 0.1-0.5 µm thick) of TiN, but the Al_2O_3 layer can be the outermost layer. This outermost layer, Al_2O_3 or TiN, has a surface roughness $R_{max} \leq 0.4$ µm over a length of 10 µm. The TiN-layer, if present, is preferably removed along the cutting edge.

According to the method of the invention a WC-Co-based cemented carbide body is made with a highly W-alloyed binder phase with a CW-ratio according to above and a content of cubic carbide according to above and a WC grain size according to above and preferably without a binder phase enriched surface zone, a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, preferably z<0.5, with a thickness of < 1.5 µm, and with equiaxed grains with size <0.5 µm using known CVD-methods.

- a layer of $TiC_xN_yO_z$ x+y+z=1, preferably with z=0 and x >0.3 and y>0.3, with a thickness of 1-6 µm, preferably 2-5 µm, with columnar grains and with an average diameter of about <5 µm, preferably <2 µm, using preferably MTCVD-technique (using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of 700-900 °C). The exact conditions, however, depend to a certain extent on the design of the equipment used.

- a smooth Al_2O_3-layer essentially consisting of κ-Al_2O_3 is deposited under conditions disclosed in e.g. EP-A-523 021. The Al_2O_3 layer has a thickness of 0.5-5 µm, preferably 0.5-2 µm, and most preferably 0.5-1.5 µm. Preferably, a further layer (<1 µm, preferably 0.1-0.5 µm thick) of TiN is deposited, but the Al_2O_3 layer can be the outermost layer. This outermost layer, Al_2O_3 or TiN,

has a surface roughness $R_{max}\leq0.4$ µm over a length of 10 µm. The smooth coating surface can be obtained by a gentle wet-blasting the coating surface with finegrained (400-150 mesh) alumina powder or by brushing (preferably used when TiN top coating is present) the edges with brushes based on e.g. SiC as disclosed e.g. in Swedish patent application 9402543-4. The TiN-layer, if present, is preferably removed along the cutting edge.

Example 1

A. A cemented carbide milling tool in accordance with the invention, inserts of style SEKN 1204 AZ with the composition 9.1 wt-% Co, 1.25 wt-% TaC, 0.30 wt-% NbC and balance WC, with a binder phase highly alloyed with W corresponding to a CW-ratio of 0.86 were coated with a 0.5 µm equiaxed TiCN-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 4 µm thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 885-850 °C and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.0 µm thick layer of Al_2O_3 was deposited using a temperature 970 °C and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3 µm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100 % κ-phase. The cemented carbide body had a WC grain size in average of 1.65 µm. The coated inserts were brushed by a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light microscope showed that the thin TiN-layer had been brushed away only along the cutting edge leaving there a smooth Al_2O_3-layer surface. Coating thickness measurements on cross sectioned brushed samples showed no reduction of the coating along

the edge line except for the outer TiN-layer that was removed.

B. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer was selected for comparison in a wet milling test. The carbide had a composition of 9.0 wt-% Co, 0.2 wt-% TiC, 0.5 wt-% TaC, 0.1 wt% NbC balance WC and a CW-ratio of 0.95. The WC-grain size was 2.5 µm. The insert had a coating consisting of a 6 µm TiCN layer and a 0.3 µm TiN layer.

Insert from A was compared against insert from B in a wet milling test in a medium alloyed steel (HB≐310) with hot rolled surfaces. Two parallel bars each of a thickness of 35 mm were central positioned relatively the cutter body (diameter 100 mm), and the bars were placed with an air gap of 10 mm between them.

The cutting data were:

Speed= 160 m/min,

Feed= 0.20 mm/rev

Cutting depth= 2 mm, single tooth milling with coolant.

A comparison was made after milling 1200 mm. Variant A according to the invention, showed no comb cracks and variant B showed 14 comb cracks. After milling 1800 mm variant B broke down due to a lot of chipping and fracture between the comb cracks. Variant A according to the invention lasted 4200 mm corresponding to an effective tool life of 11 min compared with about 4 min for variant B.

Example 2

A. A cemented carbide milling tool in accordance with the invention, inserts of style SEKN 1204 AZ with the composition 9.1 wt-% Co, 1.23 wt-% TaC, 0.30 wt-% NbC and balance WC, with a binder phase highly alloyed

with W corresponding to a CW-ratio of 0.85 were coated with a 0.5 µm equiaxed TiCN-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 3.7 µm thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 885-850 °C and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 0.9 µm thick layer of Al_2O_3 was deposited using a temperature 970 °C and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3 µm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100 % κ-phase. The cemented carbide body had a WC grain size in average of 1.6 µm.

B. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading cemented carbide producer was selected for comparison in a wet milling test. The carbide had a composition of 11.0 wt-% Co, 0.2 wt-% TaC, 0.3 wt% NbC balance WC and a CW-ratio of 0.90. The insert had a coating consisting of a 0.5 µm equiaxed TiCN layer, 2.0 µm TiCN columnar layer, 2.0 µm κ-Al_2O_3-layer and a 0.3 µm TiN-layer.

C. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer. The carbide had a composition of 7.5 wt-% Co, 0.4 wt-% TaC, 0.1 wt% NbC, 0.3 wt% TiC balance WC and a CW-ratio of 0.95. The insert had a coating consisting of a 0.5 µm equiaxed TiCN-layer, 2.1 µm columnar TiCN-layer, 2.2 µm κ-Al_2O_3-layer and a 0.3 µm TiN-layer.

Inserts from A were compared against inserts from B and C in a wet milling test in a low alloyed steel (HB=190) with hot rolled surfaces. The bars were as very common extremely rusty due to outdoor stocking. Two parallel bars each of a thickness of 32 mm were central positioned relatively the cutter body (diameter 100 mm),

and the bars were placed with an air gap of 10 mm between them.

The cutting data were:

Speed= 150 m/min,

Feed= 0.20 mm/rev

Cutting depth= 2 mm, single tooth milling with coolant.

The insert C broke after 1100 mm, the insert B broke after 2150 mm and the insert A, according to the invention, broke after 2400 mm.

In this test all coatings were of similar type, and the major difference were on the cemented carbide. The results show that the coated cemented carbide according to the invention exhibited longer tool life than two important competitor grades containing less and more binder phase resp than the coated grade according to the invention.

Example 3

A. A cemented carbide milling tool in accordance with the invention, inserts of style SEKN 1204 AZ with the composition 9.1 wt-% Co, 1.23 wt-% TaC, 0.30 wt-% NbC and balance WC, with a binder phase highly alloyed with W corresponding to a CW-ratio of 0.86 were coated with a 0.5 µm equiaxed TiCN-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 3.7 µm thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 885-850 °C and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.1 µm thick layer of Al_2O_3 was deposited using a temperature of 970 °C and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3 µm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100

% κ-phase. The cemented carbide body had a WC grain size in average of 1.7 μm. The coated inserts were brushed by a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light microscope showed that the thin TiN-layer had been brushed away only along the cutting edge leaving there a smooth Al_2O_3-layer surface. Coating thickness measurements on cross sectioned brushed samples showed no reduction of the coating along the edge line except for the outer TiN-layer that was removed.

B. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer. The carbide had a composition of 8.0 wt-% Co, 1.9 wt-% TaC, 0.2 wt% NbC, 0.2 wt% TiC balance WC and a CW-ratio of 0.85. The insert had a coating consisting of a 1.1 μm TiN layer and 3.3 μm TiC layer.

C. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer. The carbide had a composition of 10.0 wt-% Co, 2.0 wt-% TaC, 0.2 wt% TiC. balance WC and a CW-ratio of 0.90. The insert had a coating consisting of a 0.5 μm equiaxed TiCN layer, 3.3 μm TiCN columnar layer, 0.7 μm κ-Al_2O_3-layer and a 0.5 μm TiN layer.

Inserts from A was compared against inserts from B and C in a dry milling test in a low alloyed steel (HB=290) with pre machined surfaces. A bar with a thickness of 180 mm were central positioned relatively the cutter body (diameter 250 mm)

The cutting data were:

Speed= 204 m/min,

Feed= 0.22 mm/rev

Cutting depth= 2 mm, single tooth milling dry conditions.

Insert B broke after 5000 mm after comb crack formation and chipping. Insert C broke after 5400 mm by simi-

lar wear pattern and insert A was stopped after 6000 mm without other visible wear than a few small comb cracks.

Claims

1. A cutting tool insert for milling low and medium alloyed steels with or without raw surfaces during wet or dry conditions comprising a cemented carbide body and a coating c h a r a c t e r i z e d in that said cemented carbide body comprises WC, 8.6-9.5 wt-% Co and 0.2-1.8 wt-% cubic carbides of Ta, Ti and Nb, with Ti present on a level corresponding to a technical impurity, and a highly W-alloyed binder phase with a CW-ratio of 0.78-0.93 and in that said coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably $z<0.5$, with a thickness of 0.1-1.5 μm, and with equiaxed grains with size <0.5 μm

- a layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably with $z=0$ and $x>0.3$ and $y>0.3$, with a thickness of 1-6 μm with columnar grains with a diameter of about <5 μm

- a layer of a smooth, fine-grained (0.5-2 μm) κ-Al_2O_3 with a thickness of 0.5-5 μm and

- preferably an outer layer of TiN with a thickness of <1 μm.

2. Milling insert according to claim 1 c h a r a c t e r i z e d in that the cemented carbide has the composition 8.8-9.4 wt-% Co and 0.4-1.8 wt% carbides of Ta and Nb.

3. Milling insert according to any of the preceding claims c h a r a c t e r i z e d in a CW-ratio of 0.82-0.90.

4. Milling insert according to any of the preceding claims c h a r a c t e r i z e d in that the outermost TiN-layer, if present, has been removed along the cutting edge.

5. Method of making a milling insert comprising a cemented carbide body and a coating c h a r a c t e r i z e d in that a WC-Co-based cemented

carbide body with a highly W-alloyed binder phase with a CW-ratio of 0.78-0.93 is coated with

- a first (innermost) layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably $z<0.5$, with a thickness of 0.1-1.5 µm, with equiaxed grains with size <0.5 µm using known CVD-methods

- a layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably with $z=0$ and $x>0.3$ and $y>0.3$, with a thickness of 1-6 µm with columnar grains with a diameter of about <5 µm deposited by MTCVD-technique, using acetonitrile as the carbon and nitrogen source for forming the layer in a preferred temperature range of 850-900 °C.

- a layer of a smooth κ-Al_2O_3 with a thickness of 0.5-5 µm and

- preferably a layer of TiN with a thickness of <1 µm.

6. Method according to the previous claim characterized in that said cemented carbide body has a cobalt content of 8.8-9.4 wt% and 0.4-1.8 wt% cubic carbides of Ta and Nb.

7. Method according to any of the claims 5 and 6 characterized in a CW-ratio of 0.82-0.90.

8 . Method according to any of the claims 5, 6 and 7 characterized in that the outermost TiN-layer, if present, is removed along the cutting edge.

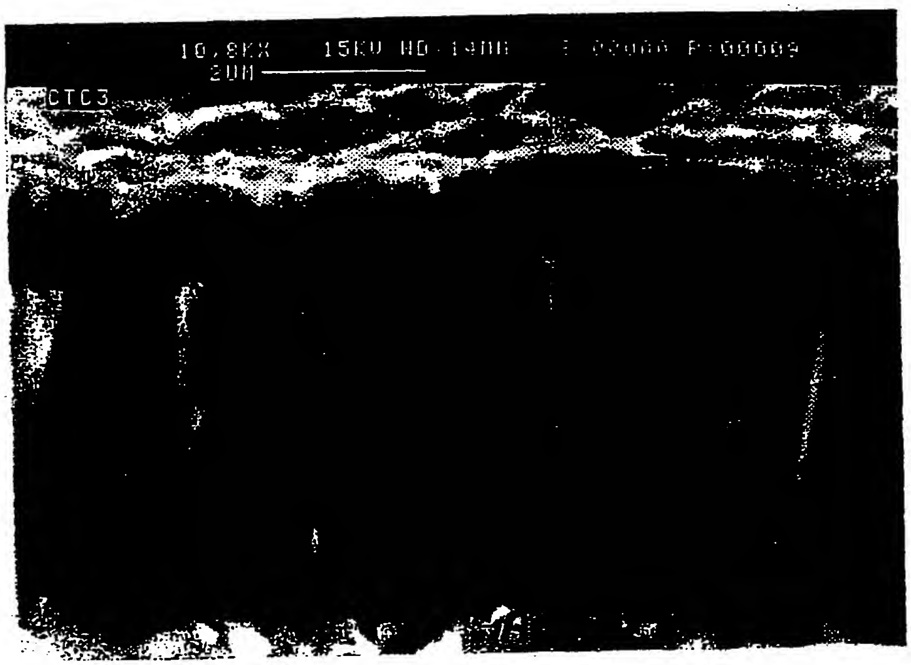

Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 96/01577

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C23C 16/30, C23C 16/40, C23C 30/00, B23B 27/14

According to International Patent Classification (IPC) or to both national classification and IPC

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Minimum documentation searched (classification system followed by classification symbols)

IPC6: C23C, B23B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Patent Abstracts of Japan, Vol 18,No 392, C-1228, abstract of JP,A,6-108254 (MITSUBISHI MATERIALS CORP), 19 April 1994 (19.04.94), & JP,A, 6108254 --	1-8
Y	Patent Abstracts of Japan, Vol 18,No 203, M-1590, abstract of JP,A,6-8008 (MITSUBISHI MATERIALS CORP), 18 January 1994 (18.01.94), & JP,A,6008008 (see p. 3, 6-7) --	1-8
Y	EP 0408535 A1 (SECO TOOLS AB), 16 January 1991 (16.01.91), column 1, line 5 - line 12; column 5, line 56 - column 6, line 25 --	1-8

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0594875 A1 (MITSUBISHI MATERIALS CORPORATION), 4 May 1994 (04.05.94), page 13, line 25 - line 35, abstract --	1-8
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COATED MILLING INSERT AND METHOD OF MAKING IT

The present invention relates to a coated cutting tool (cemented carbide insert) particularly useful for wet and dry milling of low and medium alloyed steels, with raw surfaces such as cast skin, forged skin, hot or cold rolled skin or pre-machined surfaces.

When milling low and medium alloyed steels with cemented carbide tools the cutting edge is worn according to different wear mechanisms, such as chemical wear, abrasive wear, adhesive wear and by edge chipping caused by cracks formed along the cutting edge, the so called comb cracks.

The comb crack formation is particularly severe when wet milling is employed (using coolant). Coolant and work piece material may penetrate and widen the comb cracks and the edge will start to chip. A chipped edge will generate a bad surface finish of the machined component.

Different cutting conditions require different properties of the cutting insert. For example, when cutting in steels with raw surface zones a coated cemented carbide insert must consist of a tough carbide and have very good coating adhesion. When milling in low alloyed steels the adhesive wear is generally the dominating wear type. Here preferably thin (1-3 µm) CVD- or PVD-coatings have to be used.

Measures can be taken to improve the cutting performance with respect to a specific wear type. However, very often such action will have a negative effect on other wear properties.

The influence of some possible measures is given below:

1.) Comb crack formation can be reduced by lowering the binder phase content. However, such action will

lower the toughness properties of the cutting inserts which is not desirable.

2.) Improved abrasive wear can be obtained by increasing the coating thickness. However, thick coatings increase the risk for flaking and will lower the resistance to adhesive wear.

3.) Milling at high cutting speeds and at high cutting edge temperatures requires a cemented carbide with a rather high amount of cubic carbides (solid solution of WC-TiC-TaC-NbC). Such carbides will more easily develop comb cracks.

So far it has been very difficult to improve all tool properties simultaneously. Commercial cemented carbide grades have therefore been optimized with respect to one or few of these wear types and hence to specific application areas.

Swedish patent application 9501286-0 discloses a coated cutting insert particularly useful for dry milling of grey cast iron. The insert is characterized by a straight WC-Co cemented carbide grade and a coating including a layer of $TiC_xN_yO_z$ with columnar grains and a top layer of fine grained textured α-Al_2O_3.

Swedish patent application 9502640-7 discloses a coated turning insert particularly useful for intermittent turning in low alloyed steel. The insert is characterized by a WC-Co cemented carbide body having a highly W-alloyed Co-binder phase and a coating including a layer of $TiC_xN_yO_z$ with columnar grains and a top layer of a fine grained, textured α-Al_2O_3.

Swedish patent application 9503056-5 discloses a coated turning cutting tool particularly useful for cutting in hot and cold forged low alloyed steel. The insert is characterized by a WC-Co cemented carbide body having a highly W-alloyed Co-binder phase and a coating

including a layer of $TiC_xN_yO_z$ with columnar grains and a top layer of a fine-grained, α-Al_2O_3.

It has now surprisingly been found that by combining many different features a cutting tool for milling with excellent cutting performance in low and medium alloyed steel with or without raw surface zones both in wet and dry milling can be obtained. The cutting tool according to the invention shows improved properties with respect to many of the wear types earlier mentioned.

The milling cutting insert according to the invention consists of: a cemented carbide body with a highly W-alloyed binder phase and with a well balanced chemical composition and grain size of the WC, a columnar $TiC_xN_yO_z$-layer, a κ-Al_2O_3-layer, a TiN-layer and optionally followed by smoothening the cutting edges by brushing the edges with e.g. a SiC based brush.

Fig 1 is a micrograph in 10000 X magnification of a coated insert according to the present invention in which

A - cemented carbide body

B - $TiC_xN_yO_z$-layer with equiaxed grains

C - $TiC_xN_yO_z$-layer with columnar grains

D - κ-Al_2O_3-layer with columnar like grains

E - TiN-layer preferred, could be an option

According to the present invention a milling tool insert is provided with a cemented carbide body with a composition of 8.6-9.5 wt% Co, preferably 8.7-9.5 wt% Co, most preferably 8.8-9.4 wt% Co, 0.2-1.8 wt% cubic carbides, preferably 0.4-1.8 wt% cubic carbides, most preferably 0.5-1.7 wt% cubic carbides of the metals Ta, Nb and Ti and balance WC. The cemented carbide may also contain other carbides from elements from group IVb, Vb or VIb of the periodic table. The content of Ti is preferably on a level corresponding to a technical impu-

rity. The average grain size of the WC is in the range of about 1.5-2 µm, preferably about 1.7 µm.

The cobalt binder phase is highly alloyed with W. The content of W in the binder phase can be expressed as the CW-ratio= M_S / (wt% Co · 0.0161), where M_S is the measured saturation magnetization of the cemented carbide body in kA/m and wt% Co is the weight percentage of Co in the cemented carbide. The CW-value is a function of the W content in the Co binder phase. A low CW-value corresponds to a high W-content in the binder phase.

It has now been found according to the present invention that improved cutting performance is achieved if the cemented carbide body has a CW-ratio of 0.78-0.93, preferably 0.80-0.91, and most preferably 0.82-0.90. The cemented carbide may contain small amounts, <1 volume %, of η-phase (M_6C), without any detrimental effect. From the CW-value it follows that no free graphite is allowed in the cemented carbide body according to the present invention.

The cemented carbide body may contain a thin (about 5-25 µm) surface zone depleted in cubic carbides and often enriched in binder phase according to prior art such as disclosed in US 4,610,931. In this case the cemented carbide may contain carbonitride or even nitride.

The coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, preferably z<0.5, with equiaxed grains with size <0.5 µm and a total thickness <1.5 µm and preferably >0.1 µm.

- a layer of $TiC_xN_yO_z$ with x+y+z=1, preferably with z=0 and x>0.3 and y>0.3, with a thickness of 1-6 µm, preferably 2-5 µm, with columnar grains and with an average diameter of about <5 µm, preferably 0.1-2 µm

- a layer of a smooth, fine-grained (grain size about 0.5-2 µm) Al_2O_3 consisting essentially of the κ-

phase. However, the layer may contain small amounts, 1-3 vol-%, of the θ- or the α-phases as determined by XRD-measurement. The Al_2O_3-layer has a thickness of 0.5-5 µm, preferably 0.5-2 µm, and most preferably 0.5-1.5 µm. Preferably, this Al_2O_3-layer is followed by a further layer (<1 µm, preferably 0.1-0.5 µm thick) of TiN, but the Al_2O_3 layer can be the outermost layer. This outermost layer, Al_2O_3 or TiN, has a surface roughness $R_{max} \leq 0.4$ µm over a length of 10 µm. The TiN-layer, if present, is preferably removed along the cutting edge.

According to the method of the invention a WC-Co-based cemented carbide body is made with a highly W-alloyed binder phase with a CW-ratio according to above and a content of cubic carbide according to above and a WC grain size according to above and preferably without a binder phase enriched surface zone, a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, preferably z<0.5, with a thickness of < 1.5 µm, and with equiaxed grains with size <0.5 µm using known CVD-methods.

- a layer of $TiC_xN_yO_z$ x+y+z=1, preferably with z=0 and x >0.3 and y>0.3, with a thickness of 1-6 µm, preferably 2-5 µm, with columnar grains and with an average diameter of about <5 µm, preferably <2 µm, using preferably MTCVD-technique (using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of 700-900 °C). The exact conditions, however, depend to a certain extent on the design of the equipment used.

- a smooth Al_2O_3-layer essentially consisting of κ-Al_2O_3 is deposited under conditions disclosed in e.g. EP-A-523 021. The Al_2O_3 layer has a thickness of 0.5-5 µm, preferably 0,.5-2 µm, and most preferably 0.5-1.5 µm. Preferably, a further layer (<1 µm, preferably 0.1-0.5 µm thick) of TiN is deposited, but the Al_2O_3 layer can be the outermost layer. This outermost layer, Al_2O_3 or TiN,

has a surface roughness $R_{max} \leq 0.4$ µm over a length of 10 µm. The smooth coating surface can be obtained by a gentle wet-blasting the coating surface with finegrained (400-150 mesh) alumina powder or by brushing (preferably used when TiN top coating is present) the edges with brushes based on e.g. SiC as disclosed e.g. in Swedish patent application 9402543-4. The TiN-layer, if present, is preferably removed along the cutting edge.

Example 1

A. A cemented carbide milling tool in accordance with the invention, inserts of style SEKN 1204 AZ with the composition 9.1 wt-% Co, 1.25 wt-% TaC, 0.30 wt-% NbC and balance WC, with a binder phase highly alloyed with W corresponding to a CW-ratio of 0.86 were coated with a 0.5 µm equiaxed TiCN-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 4 µm thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 885-850 °C and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.0 µm thick layer of Al_2O_3 was deposited using a temperature 970 °C and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3 µm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100 % κ-phase. The cemented carbide body had a WC grain size in average of 1.65 µm. The coated inserts were brushed by a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light microscope showed that the thin TiN-layer had been brushed away only along the cutting edge leaving there a smooth Al_2O_3-layer surface. Coating thickness measurements on cross sectioned brushed samples showed no reduction of the coating along

the edge line except for the outer TiN-layer that was removed.

B. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer was selected for comparison in a wet milling test. The carbide had a composition of 9.0 wt-% Co, 0.2 wt-% TiC, 0.5 wt-% TaC, 0.1 wt% NbC balance WC and a CW-ratio of 0.95. The WC-grain size was 2.5 µm. The insert had a coating consisting of a 6 µm TiCN layer and a 0.3 µm TiN layer.

Insert from A was compared against insert from B in a wet milling test in a medium alloyed steel (HB=310) with hot rolled surfaces. Two parallel bars each of a thickness of 35 mm were central positioned relatively the cutter body (diameter 100 mm), and the bars were placed with an air gap of 10 mm between them.

The cutting data were:

Speed= 160 m/min,

Feed= 0.20 mm/rev

Cutting depth= 2 mm, single tooth milling with coolant.

A comparison was made after milling 1200 mm. Variant A according to the invention, showed no comb cracks and variant B showed 14 comb cracks. After milling 1800 mm variant B broke down due to a lot of chipping and fracture between the comb cracks. Variant A according to the invention lasted 4200 mm corresponding to an effective tool life of 11 min compared with about 4 min for variant B.

Example 2

A. A cemented carbide milling tool in accordance with the invention, inserts of style SEKN 1204 AZ with the composition 9.1 wt-% Co, 1.23 wt-% TaC, 0.30 wt-% NbC and balance WC, with a binder phase highly alloyed

with W corresponding to a CW-ratio of 0.85 were coated with a 0.5 µm equiaxed TiCN-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 3.7 µm thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 885-850 °C and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 0.9 µm thick layer of Al_2O_3 was deposited using a temperature 970 °C and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3 µm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100 % κ-phase. The cemented carbide body had a WC grain size in average of 1.6 µm.

B. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading cemented carbide producer was selected for comparison in a wet milling test. The carbide had a composition of 11.0 wt-% Co, 0.2 wt-% TaC, 0.3 wt% NbC balance WC and a CW-ratio of 0.90. The insert had a coating consisting of a 0.5 µm equiaxed TiCN layer, 2.0 µm TiCN columnar layer, 2.0 µm κ-Al_2O_3-layer and a 0.3 µm TiN-layer.

C. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer. The carbide had a composition of 7.5 wt-% Co, 0.4 wt-% TaC, 0.1 wt% NbC, 0.3 wt% TiC balance WC and a CW-ratio of 0.95. The insert had a coating consisting of a 0.5 µm equiaxed TiCN-layer, 2.1 µm columnar TiCN-layer, 2.2 µm κ-Al_2O_3-layer and a 0.3 µm TiN-layer.

Inserts from A were compared against inserts from B and C in a wet milling test in a low alloyed steel (HB=190) with hot rolled surfaces. The bars were as very common extremely rusty due to outdoor stocking. Two parallel bars each of a thickness of 32 mm were central positioned relatively the cutter body (diameter 100 mm),

and the bars were placed with an air gap of 10 mm between them.

The cutting data were:

Speed= 150 m/min,

Feed= 0.20 mm/rev

Cutting depth= 2 mm, single tooth milling with coolant.

The insert C broke after 1100 mm, the insert B broke after 2150 mm and the insert A, according to the invention, broke after 2400 mm.

In this test all coatings were of similar type, and the major difference were on the cemented carbide. The results show that the coated cemented carbide according to the invention exhibited longer tool life than two important competitor grades containing less and more binder phase resp than the coated grade according to the invention.

Example 3

A. A cemented carbide milling tool in accordance with the invention, inserts of style SEKN 1204 AZ with the composition 9.1 wt-% Co, 1.23 wt-% TaC, 0.30 wt-% NbC and balance WC, with a binder phase highly alloyed with W corresponding to a CW-ratio of 0.86 were coated with a 0.5 µm equiaxed TiCN-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 3.7 µm thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 885-850 ^{o}C and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.1 µm thick layer of Al_2O_3 was deposited using a temperature of 970 ^{o}C and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3 µm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100

% κ-phase. The cemented carbide body had a WC grain size in average of 1.7 μm. The coated inserts were brushed by a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light microscope showed that the thin TiN-layer had been brushed away only along the cutting edge leaving there a smooth Al_2O_3-layer surface. Coating thickness measurements on cross sectioned brushed samples showed no reduction of the coating along the edge line except for the outer TiN-layer that was removed.

B. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer. The carbide had a composition of 8.0 wt-% Co, 1.9 wt-% TaC, 0.2 wt% NbC, 0.2 wt% TiC balance WC and a CW-ratio of 0.85. The insert had a coating consisting of a 1.1 μm TiN layer and 3.3 μm TiC layer.

C. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer. The carbide had a composition of 10.0 wt-% Co, 2.0 wt-% TaC, 0.2 wt% TiC. balance WC and a CW-ratio of 0.90. The insert had a coating consisting of a 0.5 μm equiaxed TiCN layer, 3.3 μm TiCN columnar layer, 0.7 μm κ-Al_2O_3-layer and a 0.5 μm TiN layer.

Inserts from A was compared against inserts from B and C in a dry milling test in a low alloyed steel (HB=290) with pre machined surfaces. A bar with a thickness of 180 mm were central positioned relatively the cutter body (diameter 250 mm)

The cutting data were:

Speed= 204 m/min,

Feed= 0.22 mm/rev

Cutting depth= 2 mm, single tooth milling dry conditions.

Insert B broke after 5000 mm after comb crack formation and chipping. Insert C broke after 5400 mm by simi-

lar wear pattern and insert A was stopped after 6000 mm without other visible wear than a few small comb cracks.

Claims

1. A cutting tool insert for milling low and medium alloyed steels with or without raw surfaces during wet or dry conditions comprising a cemented carbide body and a coating characterized in that said cemented carbide body comprises WC, 8.6-9.5 wt-% Co and 0.2-1.8 wt-% cubic carbides of Ta, Ti and Nb, with Ti present on a level corresponding to a technical impurity, and a highly W-alloyed binder phase with a CW-ratio of 0.78-0.93 and in that said coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably $z<0.5$, with a thickness of 0.1-1.5 μm, and with equiaxed grains with size <0.5 μm

- a layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably with $z=0$ and $x>0.3$ and $y>0.3$, with a thickness of 1-6 μm with columnar grains with a diameter of about <5 μm

- a layer of a smooth, fine-grained (0.5-2 μm) κ-Al_2O_3 with a thickness of 0.5-5 μm and

- preferably an outer layer of TiN with a thickness of <1 μm.

2. Milling insert according to claim 1 characterized in that the cemented carbide has the composition 8.8-9.4 wt-% Co and 0.4-1.8 wt% carbides of Ta and Nb.

3. Milling insert according to any of the preceding claims characterized in a CW-ratio of 0.82-0.90.

4. Milling insert according to any of the preceding claims characterized in that the outermost TiN-layer, if present, has been removed along the cutting edge.

5. Method of making a milling insert comprising a cemented carbide body and a coating characterized in that a WC-Co-based cemented

carbide body with a highly W-alloyed binder phase with a CW-ratio of 0.78-0.93 is coated with

- a first (innermost) layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably $z<0.5$, with a thickness of 0.1-1.5 µm, with equiaxed grains with size <0.5 µm using known CVD-methods

- a layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably with $z=0$ and $x>0.3$ and $y>0.3$, with a thickness of 1-6 µm with columnar grains with a diameter of about <5 µm deposited by MTCVD-technique, using acetonitrile as the carbon and nitrogen source for forming the layer in a preferred temperature range of 850-900 °C.

- a layer of a smooth κ-Al_2O_3 with a thickness of 0.5-5 µm and

- preferably a layer of TiN with a thickness of <1 µm.

6. Method according to the previous claim characterized in that said cemented carbide body has a cobalt content of 8.8-9.4 wt% and 0.4-1.8 wt% cubic carbides of Ta and Nb.

7. Method according to any of the claims 5 and 6 characterized in a CW-ratio of 0.82-0.90.

8 . Method according to any of the claims 5, 6 and 7 characterized in that the outermost TiN-layer, if present, is removed along the cutting edge.

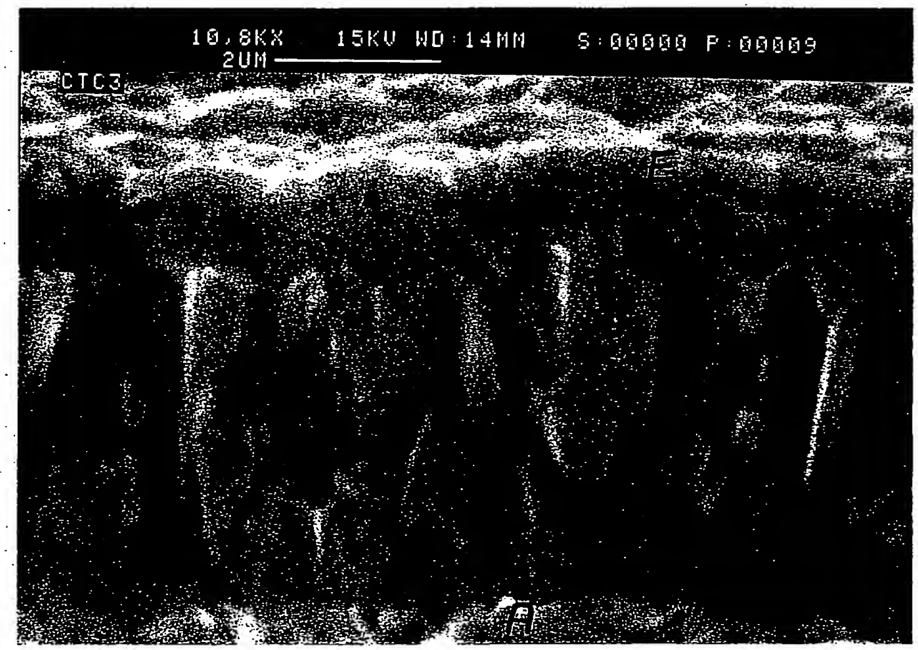

Fig. 1

5/28/98

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference UB-11460 DE	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/SE 00/01678	International filing date *(day/month/year)* 31 August 2000	(Earliest) Priority Date *(day/month/year)* 1 Sept 1999
Applicant SANDVIK AB; (publ)		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing:

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (See Box II).

4. With regard to the **title**,

[X] the text is approved as submitted by the applicant.

[ ] the text has been established by this Authority to read as follows:

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5. With regard to the **abstract**,

[X] the text is approved as submitted by the applicant.

[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. ______

[ ] as suggested by the applicant.

[ ] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

[ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/01678

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: C22C 29/08, C23C 16/30, C23C 16/40, C23C 28/00, B23B 27/14
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9720081 A1 (SANDVIK AB), 5 June 1997 (05.06.97), page 8, line 23 - line 29	1,2,5,6
A		3,4,7,8
	--	

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 December 2000	12-12-2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Nils Engnell/MP Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

02/11/00

International application No.
PCT/SE 00/01678

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9720081 A1	05/06/97	BR 9611780 A	23/02/99
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